



**US Army Corps
of Engineers®**
Engineer Research and
Development Center

In-Place Pipe Lining of Pre-action Fire Suppression System at Fort McPherson, GA

Orange S. Marshall

March 2007



In-Place Pipe Lining of Pre-action Fire Suppression System at Fort McPherson, GA

Orange S. Marshall

*Construction Engineering Research Laboratory
U.S. Army Engineer Research and Development Center
PO Box 9005
Champaign, IL 61826-9005*

Final report

Approved for public release; distribution is unlimited.

Prepared for Directorate of Public Works
Fort McPherson, GA 30330-1075

Under Work Unit 4LFJ3K

Abstract: A pre-action fire suppression system was installed in a portion of the U.S. Army Reserve Component Headquarters at Fort McPherson, GA, when the structure was constructed in 1995. This system, which is normally kept at a standard internal air pressure using air compressors in the basement electrical-mechanical room, is designed to remain dry, and have water in it only in the event of a fire. The Pre-action Fire Suppression System has developed pinhole leaks due to what appears to be galvanic corrosion. The U.S. Army Corps of Engineers Engineer Research and Development Center, Construction Engineering Research Laboratory proposed installing an in-place epoxy lining of the system using a process developed by American Pipe Lining, Inc. The in-place epoxy lining was installed in the pre-action system and the effectiveness of the coating process documented. The work included restoration and lining of all interior pre-action piping mains, risers, branch laterals, and service piping to individual sprinkler head locations installing new 1/2-inch sprinkler heads on pre-action system and pre-action system recertification. This report describes the in-place epoxy lining process and the effectiveness of the coating system to eliminate the pinhole leak problem.

DISCLAIMER: The contents of this report are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or approval of the use of such commercial products. All product names and trademarks cited are the property of their respective owners. The findings of this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

DESTROY THIS REPORT WHEN NO LONGER NEEDED. DO NOT RETURN IT TO THE ORIGINATOR.

Contents

Figures	iv
Preface	v
Unit Conversion Factors	vi
1 Introduction.....	1
Background	1
Objective	1
Approach.....	1
Mode of Technology Transfer	2
2 Pre-Implementation Condition of Fire Suppression System	3
CERL Evaluation	4
Pre-action Fire Suppression System	7
Compressed Air	8
3 Corrosion Processes in a System	9
Theory of Corrosion	9
Concentration Cell Corrosion	10
Pitting Corrosion	11
4 Pipe Coating Preparation Procedure	13
Staging of Equipment and Material	13
Inspecting Existing Fire Sprinkler System	14
Securing Existing Fire Sprinkler System.....	15
Cleaning Existing Fire Sprinkler System.....	15
Coating Existing Fire Sprinkler Piping	16
Installing New Sprinkler Heads	19
Activating Fire Suppression System	19
Testing the Activated Fire Suppression System.....	19
Recertifying the Treated Pre-action Fire Suppression System.....	19
5 Cost Analysis.....	20
6 Conclusions and Recommendations	21
Conclusions	21
Recommendations	21
References.....	22
Report Documentation Page	

Figures

Figures	Page
Figure 1 Temporary repairs made in the archives room.	3
Figure 2 Exterior of pipe section showing pinholes.....	4
Figure 3 Largest pinhole shown in Figure 2	4
Figure 4 Pipe interior showing tubercles.....	5
Figure 5 Interior of cleaned and lined pipe section	6
Figure 6 Exterior of cleaned and lined pipe section.....	6
Figure 7 Pre-action system.....	7
Figure 8 Valving in Building 315	8
Figure 9 Pipe interior before treatment.....	12
Figure 10 Pipe interior following grit blast.....	12
Figure 11 Interior of pipe following epoxy lining	12

Preface

This study was conducted for the Fort McPherson Directorate of Public Works under Project Number 121373, Work Item 4LFJ3K, "Cleaning and Epoxy Lining of existing dry System Sprinkler Piping, USARC, Building 315." The technical monitor was Len Wasendorf, USAG-DPW.

The work was performed by the Materials and Structures Branch (CF-M) of the Facilities Division (CF), Construction Engineering Research Laboratory (CERL). The CERL Principal Investigator was Orange S. Marshall, Jr. Part of this work was done by American Pipe Lining, Inc. under contract DACA42-03-C-0071 Amendment P00004. Steven Sweeney is Acting Chief, CF-M, and L. Michael Golish is Chief, CF. Technical Director of the Facilities Acquisition and Revitalization business area is William D. Goran. The Deputy Director of CERL is Dr. Kirankumar V. Topudurti, and the Director is Dr. Ilker Adiguzel.

CERL is an element of the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Commander and Executive Director of ERDC is COL Richard B. Jenkins, and the Director is Dr. James R. Houston.

Unit Conversion Factors

Multiply	By	To Obtain
inches	0.0254	Meters
degrees Fahrenheit	$(F-32)/1.8$	degrees Celsius
pounds (force) per square inch	6.894757	kilopascals

1 Introduction

Background

A pre-action fire suppression system was installed in a portion of the U.S. Army Reserve Component Headquarters when the structure was constructed at Fort McPherson, GA, in 1995. This fire suppression system, which is normally kept at a standard internal air pressure using air compressors in the basement electrical-mechanical room, is designed to remain dry and have water in it only in the event of a fire. The pre-action fire suppression system has developed pinhole leaks due to what appears to be galvanic corrosion. The U.S. Army Corps of Engineers Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL) proposed installing an in-place epoxy lining of the system using a process developed by American Pipe Lining, Inc. (APL). This system is primarily in the basement of the building and is tied into a wet system installed in the first, second and third floors of the building. The dry portion is primarily galvanized steel piping while the wet portion is a combination of black steel and copper pipe.

Objective

The objective of this work was to demonstrate/document the process and show the effectiveness of cleaning and subsequent epoxy coating, in-place, of the existing galvanized steel portion of the fire suppression system in Building 315, the U.S. Army Reserve Component Headquarters. The work included restoration and lining of all interior pre-action piping mains, risers, branch laterals and service piping to individual sprinkler head locations, to install 1/2-inch sprinkler heads on the pre-action system and to recertify the pre-action system.

Approach

The existing galvanized steel pre-action fire suppression system piping in the Computer Room on the 1st floor of the building and in the Loading Dock Area, the Archive and Special Archive areas, Emergency Operations, Security Records, and Stack Areas of the basement were lined using two coats of epoxy paint.

- The existing galvanized steel piping in the building was isolated for cleaning/epoxy lining purposes.

- The pipe segments were completely dried using hot compressed air.
- A light-abrading agent was distributed in sequenced "pulses" throughout the pipe system to remove any corrosion buildup along the pipe's interior wall and to create a suitable pipe wall anchor tooth to maximize subsequent epoxy adhesion.
- Epoxy paint was injected through the pipe system under pressure, lining the system to a minimum of 7 mils of thickness.
- Following the completion of all segments, all fittings were reconnected and tested for leaks utilizing compressed air.
- Original valves and fittings determined to be overly worn or nearly inoperable were removed and replaced following review by the Fort McPherson Directorate of Public Works (DPW). Fittings or pipe that fracture or leak during the process shall be replaced by APL.
- Upon completion of all segments, the lined system was tested and documented in accordance with National Fire Protection Association (NFPA) standards.
- After all testing of lined system was complete, a Material and Test Certificate from a licensed fire protection contractor was provided to the Fort McPherson DPW.

Mode of Technology Transfer

Modifications to existing Army criteria for fire suppression will be submitted to include the in-place pipelining process for fire suppression systems.

2 Pre-Implementation Condition of Fire Suppression System

During a visit to Fort McPherson, DPW engineers were briefed on in-situ pipe lining work performed at Fort Drum, NY, in which copper pipes were lined to eliminate lead leaching into the potable water lines from solder joints in family housing piping. Following the presentation, the DPW Deputy Director suggested that this technology could be a solution to problems they were encountering in Building 315, the U.S. Army Reserve Center headquarters building. The building was less than 5 years old and the pre-action fire suppression system in the basement was already developing pinhole leaks due to corrosion, particularly in the Archives area. Figure 1 shows some temporary repairs in the archives room.

CERL was asked to evaluate whether or not the insitu pipe lining process performed by American Pipe Lining, Inc. could be used to restore integrity to the fire suppression system, filling the pinhole leaks and lining the interior of the pre-action system in Building 315. The Fort McPherson DPW secured a 2-ft section of 4-in. diameter pipe cut from the system in the basement archives area and provided it to ERDC-CERL for evaluation.

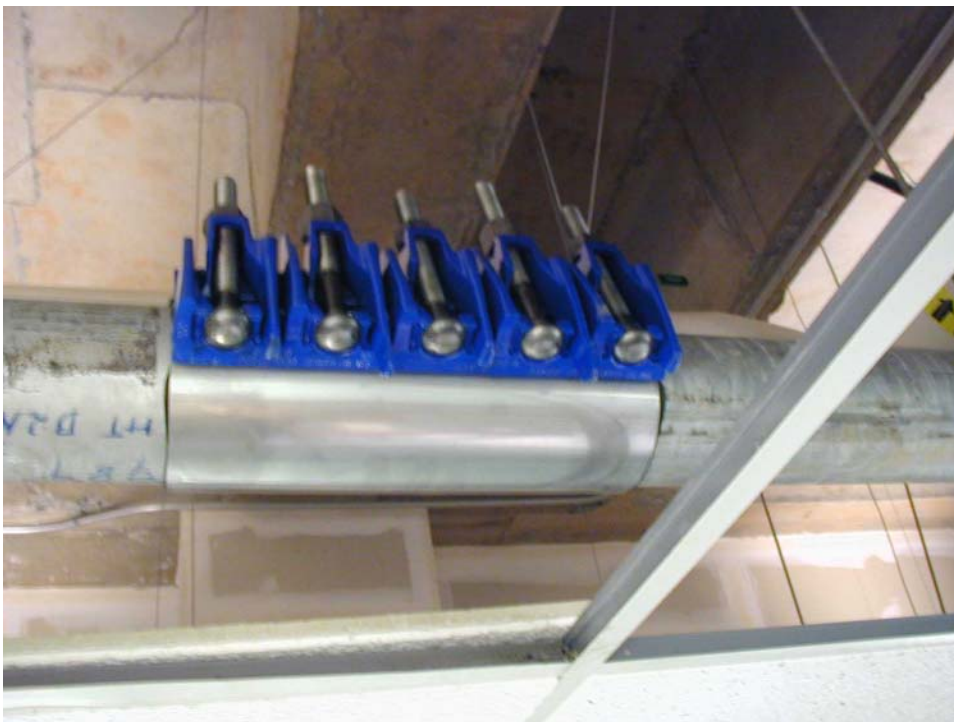


Figure 1. Temporary repairs made in the archives room.

CERL Evaluation

The pipe section provided by the Fort McPherson DPW had three visible pin holes with large tubercle growths on the interior of the pipe. Figure 2 shows the exterior of the pipe section provided. The pinholes are circled. The largest hole (Figure 3), was measured using vernier calipers to be 3/16-inch in diameter. Figure 4 shows the pipe interior clearly depicting the tubercles comprised of corrosion products from the pin holes.



Figure 2. Exterior of pipe section showing pinholes (circled in red).



Figure 3. Largest pinhole shown in Figure 2.

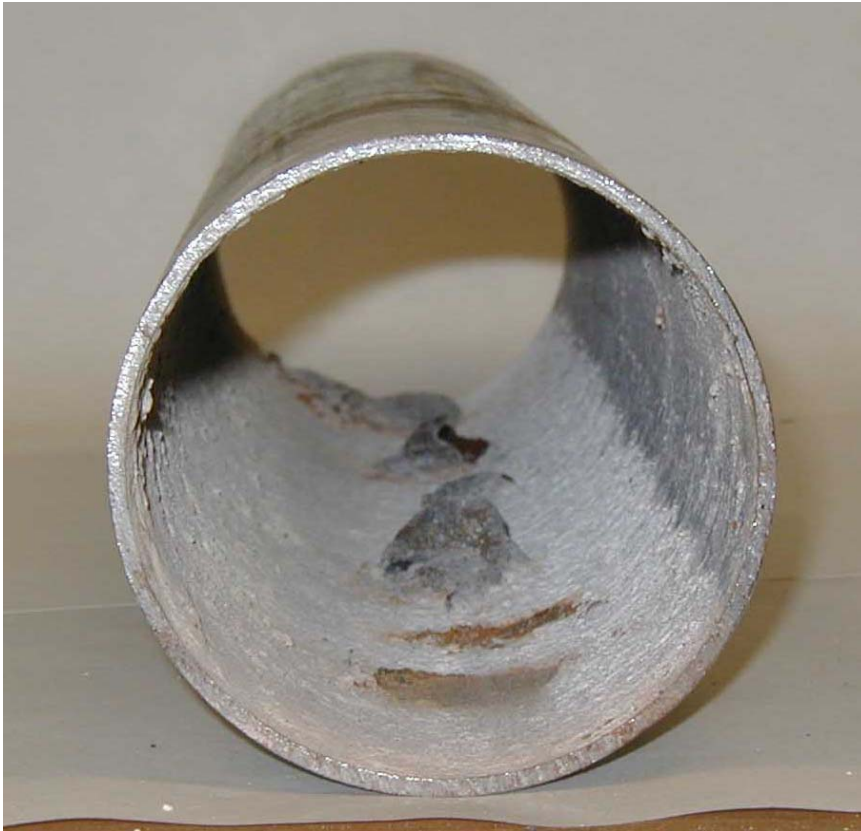


Figure 4. Pipe interior showing tubercles.

After initial evaluation by CERL, the pipe section was sent to APL, where it was lined using two coats of epoxy and pressure tested. Figures 5 and 6 show the exterior and interior respectively of the cleaned and lined pipe section. After examining the lined pipe section, the Fort McPherson DPW provided funds to line the pre-action fire support system in Building 315.



Figure 5. Interior of cleaned and lined pipe section.



Figure 6. Exterior of cleaned and lined pipe section.

Pre-action Fire Suppression System

A pre-action fire suppression system is a modified dry-pipe fire suppression system. It is essentially the same as wet-pipe systems except that the pipes in the protected area contain pressurized air rather than water. The air holds a valve closed which prevents water from entering the sprinkler piping. If a heat or smoke detector indicates a fire, a valve automatically opens, discharging the air in the pipes and permitting water to flow into the piping. The water discharges from the sprinklers that have opened due to exposure to a heat source. Figure 7 is a drawing depicting a pre-action system, and Figure 8 shows the valving in Building 315.

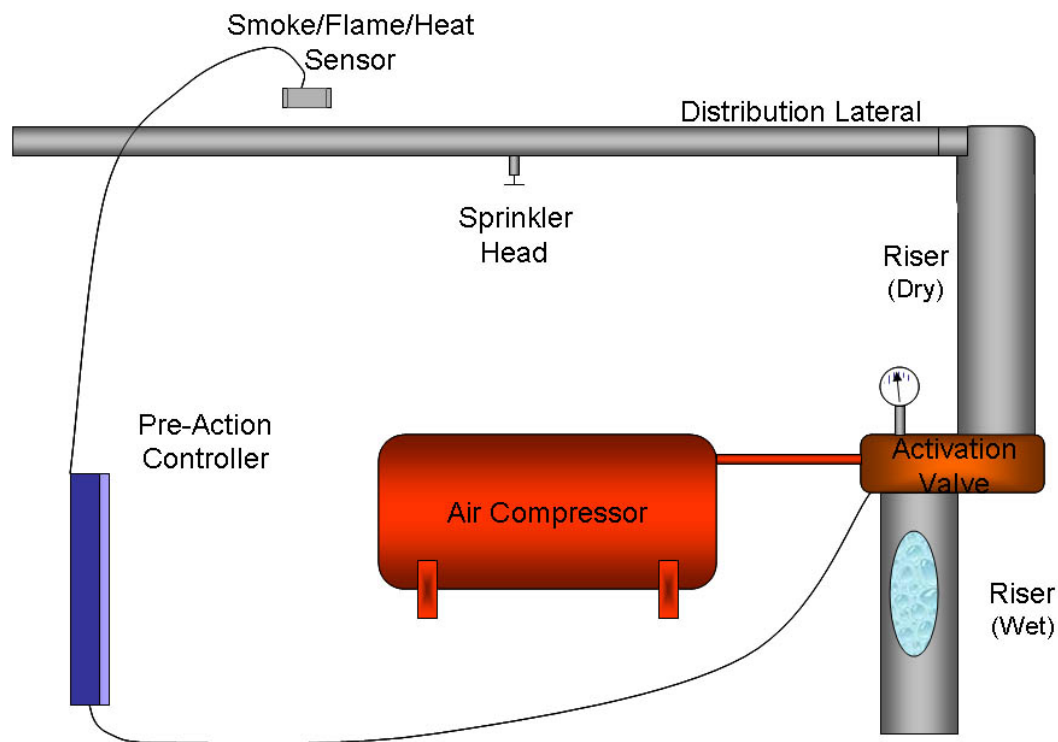


Figure 7. Pre-action system.



Figure 8. Valving in Building 315.

Compressed Air

As stated earlier, pre-action fire suppression systems rely on internal air pressure to prevent the water release valve from opening and flooding the pipelines. The air pressure requirements are maintained using compressed air provided by an air compressor. Typically, the air going through the compressor is ambient atmospheric air, which contains a percentage of water commonly referred to as relative humidity (RH). Since removal of the water in the compressed air is not practical in most instances, water enters the “dry” pipeline whenever the air compressor runs. When the air compressor operates, especially on warm, humid days, the RH of the compressed air introduced into the pipes becomes 100 percent or totally saturated. Since the pipes are in an air-conditioned space, cooler than the incoming air source, the pipes cool the compressed air, which releases water. The water condenses in the pipes and provides the electrolyte necessary for corrosion to occur. If the corrosion process proceeds to the point where pinhole leaks form, the compressor is forced to pump more air (containing more water) into the system, exacerbating the situation and accelerating the corrosion. Chapter 3 provides details of corrosion theory and process.

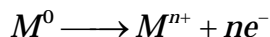
3 Corrosion Processes in a System

When metallic components are used, corrosion of some type will occur. Conditions which promote corrosion are:

- exposure of piping to corrosive soils or water;
- low-velocity, stagnant-type flow conditions;
- contact between dissimilar metals that may become immersed in a conductive medium;
- high temperatures;
- abrasive effects that may cause the surfaces of metals to be eroded;
- application of tensile stresses within a corrosive environment;
- highly acidic solutions combined with holes near metal-to-metal surfaces or near sealing surfaces; and
- any metals close to sources of atomic hydrogen.

Theory of Corrosion

Corrosion occurs by an electrochemical process. The phenomenon is similar to that which takes place when a carbon-zinc "dry" cell generates a direct current. Basically, an anode (negative electrode), a cathode (positive electrode), electrolyte (corrosive environment), and a metallic circuit connecting the anode and the cathode are required for corrosion to occur. Dissolution of metal occurs at the anode where the corrosion current enters the electrolyte and flows to the cathode. The general reaction which occurs at the anode is the dissolution of metal as ions (USACE 1999):



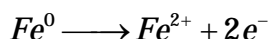
where:

M = metal involved

n = valence of the corroding metal species

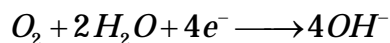
e⁻ = the loss of electrons from the anode.

For iron and steel pipe, the reaction equation becomes:



When the iron ions react with oxygen from either air or dissolved in water, it forms iron oxide or rust. Iron will not corrode in pure water in the absence of dissolved oxygen (Flinn and Trojan 1990).

At the cathode, water containing dissolved oxygen uses up the free electrons to form alkaline solutions.



Examination of these basic reactions reveals that a loss of electrons, or oxidation, occurs at the anode. The electrons lost at the anode flow through the metallic circuit to the cathode and permit a cathodic reaction (or reactions) to occur.

Pipe manufacturers, in an attempt to preclude steel corrosion in pipes, apply on the surfaces a galvanized layer or coating primarily made of zinc. Zinc is more electrochemically active than steel and becomes anodic in the event of the creation of a corrosion cell. So the zinc, rather than the steel it coats, becomes the electron source and corrodes.

Concentration Cell Corrosion

Electrochemical attack of a metal or alloy because of differences in the environment is called concentration cell corrosion. This form of corrosion is sometimes referred to as “crevice corrosion,” “gasket corrosion,” and “deposit corrosion” because it commonly occurs in localized areas where small volumes of stagnant solution exist. This is the environment inside the pre-action fire suppression system piping at Fort McPherson. Normal mechanical construction can create crevices at sharp corners, spot welds, lap joints, fasteners, flanged fittings, couplings, threaded joints, and tube-sheet supports. Deposits that promote concentration cell corrosion can come from a number of sources; other sites for crevice attack can be established when electrolyte-absorbing materials are used for gaskets and the sealing of threaded joints.

Concentration cells can occur in at least five ways:

1. Hydrogen ion
2. Neutral salt
3. Inhibition
4. Oxygen
5. Metal Ion.

Of these five, the oxygen and metal ion cells are most commonly considered in technical literature (USACE 1999).

It is known that areas on a surface in contact with an electrolyte having a high oxygen content will generally be cathodic relative to those areas where less oxygen is present. Oxygen can function as a cathodic depolarizer; in neutral and alkaline environments, regions of high oxygen would be preferred cathodic sites for the reduction of oxygen (redox). This is commonly referred to as an “oxygen concentration cell.”

A mechanism is proposed wherein the dissolution of metal (anodic process) and redox (cathodic process) initially occur uniformly over the entire surface, including the interior of the crevice. In time, the oxygen within the crevice is consumed and the localized (oxygen reduction) cathodic process stops in this area. The overall rate of redox, however, remains essentially unaltered because the area within the crevice is quite small compared to the area outside of the crevice. The rate of corrosion within and outside the crevice remains equal.

Concentration cell corrosion can occur at threaded joints of pipe used to convey aggressive liquids. When the joints are improperly sealed, rapid crevice attack occurs in the threaded area where stagnant, low-oxygen-content fluids exist. Since the wall thickness of the pipe is reduced by threading, failures due to concentration cell corrosion can be a frequent and common occurrence at threaded joints. Threaded joints sealed with liquid-absorbing materials (for example, string or hemp) can fail in as little as 9 months. Similarly, transport deposits of solids can be a major cause of concentration cell corrosion.

Pitting Corrosion

Pitting corrosion is a randomly occurring, highly localized form of attack on a metal surface. In general, it is characterized by the depth of penetration being much greater than the diameter of the area affected. Pitting is similar to concentration cell-corrosion in many respects. The two are not the same, however, because crevices, deposits, or threaded joints are not requisites for pit initiation. Further, concentration cell corrosion can occur in environments where the metal or alloy is immune to pitting attack.

Pitting attack appears to occur in two distinct stages. First, an incubation period occurs during which the pits are initiated; second, a propagation period occurs during which the pits develop and penetrate into the metal.

It is generally agreed that a sufficient concentration of an aggressive anion (generally chloride, but also bromide, iodide, and perchlorate) and an oxidizing agent (dissolved oxygen, Fe^{+++} , H_2O_2 , Cu^{++} , and certain others) must be present in the electrolyte. A stagnant volume of liquid must exist in the pit or pitting will not occur. In addition, for a given metal/electrolyte system, the redox potential must be more noble than a certain critical value. It is also agreed that the corrosion processes within the pit produce conditions of low pH and high chloride ion content; these keep the localized anodic areas electrochemically active (USACE 1999), accelerating the attack. Figures 9 through 11 document the pipe condition and treatment.



Figure 9. Pipe interior before treatment.



Figure 10. Pipe interior following grit blast.



Figure 11. Interior of pipe following epoxy lining.

4 Pipe Coating Preparation Procedure

An in-place epoxy lining developed by APL was installed in the pre-action fire suppression system of Building 315 at Fort McPherson to eliminate the chronic pinhole leak problem. The existing galvanized steel pre-action fire suppression system piping was treated first in the Computer Room on the 1st floor, followed by the Loading Dock in the basement, then the Pre-action Main supplying the Archive Area of the basement followed by the Special Archive area, the Emergency Operations area, the Security Records area, and finally the Stack Area of the basement. This chapter describes the work process used. The work included:

- restoration and lining of all interior pre-action piping mains, risers, branch laterals and service piping to individual sprinkler head locations,
- installing new 1/2-inch sprinkler heads on the pre-action system, and
- pre-action system recertification.

The work was accomplished through the following phases:

1. Staging of equipment and material
2. Inspecting the existing fire sprinkler system
3. Securing the existing fire sprinkler system
4. Cleaning the existing fire sprinkler system
5. Coating the existing fire sprinkler piping
6. Installing new sprinkler heads
7. Activating the fire suppression system
8. Testing the activated fire suppression system
9. Recertifying the treated pre-action fire suppression system

Staging of Equipment and Material

Special care was exercised in selecting equipment staging locations and hose routing configurations so as to not create unreasonable obstructions to pedestrians. An air compressor and peripheral equipment for conditioning air and collection of residue were staged in an area with direct access to Building 315. They were staged just outside the north entry door for performing the work in the Computer Room and then moved to the Loading

Dock area for the basement work. Every attempt was made to limit obstructions to pedestrians and vehicular traffic during restoration.

Air hoses were neatly routed along the inside floor area of the building corridors and stairways where applicable. Special care was also exercised in selecting hose routing configurations so as to not create unreasonable obstructions to pedestrians. An air distribution manifold (i.e., valve rack) was staged inside the building and fitted with up to 24 1-inch-diameter air hoses, which subsequently connected to fixture angle stop locations. Larger diameter hoses supplied conditioned air from the main compressor outside and routed it into the building to the air distribution manifold.

A portable vacuum system collected all spent air, abrading grit and corrosion residue into a closed dust collector and residue tank where it was filtered before allowing the spent air to re-enter the atmosphere. Dust collecting equipment with an efficiency of 99.5 percent using 0.5-micron filters was used to ensure that no solids were released into the atmosphere at any time throughout the process. All spent cleaning and coating residue (i.e., garnet sand, removed rust scale, and excess epoxy coating material) was collected and disposed of properly.

Inspecting Existing Fire Sprinkler System

The existing galvanized steel piping in the building was isolated for cleaning/epoxy lining purposes in pre-determined restoration work segments. A restoration work segment is defined as a pipe section or pipe “run” designated for cleaning/lining at any given time. As work is initiated on designated work segments, the water supply was temporarily secured at the most accessible shutoff valve(s) inside the building nearest the respective pipe segment(s) being restored.

A temporary water supply was provided and the flow rates of the steel piping systems were measured. The existing pre-action sprinkler system segment was visually inspected. Inspections note excessive “pinhole” failures or surface corrosion within each section of pipe. A section of pipe is determined to be from fitting to fitting and not longer than 21 feet measured along the center line of the pipe. Excessive wear is determined to be greater than three visible failures within each section of pipe. Less than this amount is considered isolated wear. All areas visually identified as pipe failures were noted on-site on a copy of the existing as-built drawings with a description of the findings. If a pipe system’s physical condition was in doubt (i.e., excessive pin holes, surface corrosion or visible leaks), APL

used its discretion to test for wall thickness using manual or electronic means to measure the average thickness and general condition of the pipe system.

Following the pipe system review, a determination was made as to the feasibility to proceed with restoration. Each segment of pipe was pressure tested to ensure the integrity of the pipe system prior to cleaning and coating. Manual testing was performed using a calibrated wet film thickness gauge or, when direct access to the interior of the piping was available, a probe micrometer. Electronic means were used when no direct access to the piping was available (welded piping, no flanges or unions) utilizing ultrasonic testing equipment. APL recommends that pipe measured or inspected having less than 20-30 percent of original wall thickness be replaced. In instances where isolated pinholes (1/32 inch and smaller) are found in otherwise suitable pipe surroundings as noted above, the air sand process may be used to treat and seal the isolated pinholes. For larger holes, a cover was clamped over the hole until the coating could cure properly.

Securing Existing Fire Sprinkler System

Air pressure in the pre-action fire suppression pipe segment being restored was slowly released, and the valves in the segment were removed during the set-up phase of the work. In work areas requiring temporary relocation of items that might hinder access to domestic piping (e.g., pallets, movable equipment/materials, etc.), APL notified the building owner in advance before moving anything. For the duration of system “down time,” the installation was responsible for posting a fire watch within the affected areas in coordination with the installation fire marshal.

The APL process requires attachment of an air hose to each input location (i.e., at 1/2-, 3/4-, or 1-inch pipe nipple connection points at sprinkler heads) in the segment being processed. Quick disconnect pipe nipples were attached to the sprinkler heads and to a previously identified main exhaust point.

Cleaning Existing Fire Sprinkler System

To ensure a tight bond between the epoxy lining and the pipe wall, it was necessary to clean and abrasively blast the interior of the steel piping systems before the epoxy coating was applied. The cleaning process is described below.

Heated, oil-free compressed air was routed through a manifold and through the pipes in the segments to de-water and dry the piping. The air was heated to a predetermined temperature of 155 °F (68 °C). The initial pipe dryness was verified by opening the exhaust valve at the end of the run slightly and allowing the exhaust air to vent with a audible flow into an open dry container for 1 minute. Any wetting or staining of the container indicated moisture or contamination.

When the pipe segment was completely dried, a light-abrading agent was distributed in sequenced “pulses” throughout the pipe system to remove any corrosion buildup along the pipe's interior wall. The garnet sand used was a nontoxic, State-approved abrading material. This served to further dry the pipe surface and create a suitable pipe wall anchor tooth to maximize subsequent epoxy adhesion. The prepared surface had a near white-metal blast appearance (conforming to Society for Protective Coatings [SSPC] SP10 Standards), and an anchor tooth (not peened) surface profile of 50 to 75 micrometers (2 to 3 mils) which is measured at the pipe inlet and outlet with profile tape and a dial or probe micrometer. The sand was collected by the portable vacuum system.

Air surging was then used to clean pipes and remove remaining dust and other debris. Pipe inspection after cleaning verified that the interior surfaces of the piping systems were properly prepared to ensure optimal conditions for epoxy coating adhesion. Once cleaned and inspected, the piping system was ready for coating.

Any piping sections or fittings that were not treatable due to (1) related excessive wear (i.e., leaking, thin-walled pipe and/or pipe threads), or (2) fully or partially blocked corrosion products and residue sufficient to restrict adequate air flow into the pipe for cleaning purposes, was replaced with new galvanized steel pipe to maintain the integrity of the overall piping system. Where pipe replacement was required, APL consulted with the owner before pipe restoration commenced. In those cases where untreatable pipe requiring replacement was discovered, APL replaced the pipe section or fitting(s) in order to continue work. The removed pipe or fitting(s) were retained and made available to the owner the following day for inspection and review.

Coating Existing Fire Sprinkler Piping

Piping cleaned and lined via the APL air-sand-vacuum process provides a permanent protective barrier within the pipe interior wall to halt any fur-

ther deterioration of the piping system. The epoxy coating applied to the pipe interior was formulated from 100 percent solids in weight and volume (i.e., no solvents), was nontoxic, and was approved for use in potable water piping systems in accordance with National Sanitation Foundation (NSF) Standard 61. The minimum coating thickness was 7-9 mils per coat.

Effective coating requires the pipe temperature to be raised and maintained at least 10 °F (-12 °C) above the dew point as established with site readings using a digital temperature, RH, and dew point meter. Readings were documented in the daily Epoxy Lining Production Report. The surface also requires protection from finger marks, oils, and other contaminants that may compromise the bonding efficacy of the epoxy coating. The air stream was sampled with a digital temperature, RH, and dew point meter prior to pipe lining at the exhaust (exit) end of the piping section being treated. These tests determine discharge temperatures and assess any presence of moisture in the air supply.

Based on air temperature and moisture dynamics in the treatment environment, the epoxy coating was applied in pre-measured quantities throughout the designated pipe section using the heated, conditioned air as the transport medium. Continuous, positive air flow at regulated temperatures were maintained and monitored at the discharge point by continuous testing with a digital thermometer at all times before, during, and following introduction of the epoxy lining into the piping to prevent moisture contamination of the coating. Sampling results were noted in the Epoxy Lining Production Report.

Thickness measurements were performed using a calibrated wet film thickness gauge following application of the epoxy coating, or by using a dry film thickness gauge/probe after the coating had set or cured. A coating thickness of 7 mils was maintained with a minimum coating thickness of 5-6 mils average on all pipe sides. Use of 100 percent solids coatings eliminates any shrinkage of the coating following application (i.e., wet mil film thickness = dry mil film thickness).

Applying the coating, which was specifically formulated for compatibility with potable water, was a precise and complex evolution. The contractor coated test panels, which were inspected and accepted by the Contracting Officer prior to coating entire piping systems. The air in the pipe was heated to achieve an optimal coating environment within the pipe. Optimal coating environment (viscosity, curing time) is between 60 and 100 °F

(15 and 37 °C). Distributing epoxy coating throughout pipe lengths was achieved using heated compressed air. The temperature applied on the epoxy coating was maintained within these bounds throughout the application process. The maximum pressure applied inside the water distribution pipe system was below 80 psi during all phases of the application process. The epoxy coating could not be applied to pipes and fittings with less than 40 percent of their original wall thickness, so wall thickness was verified prior to application.

Once the pipe had reached the proper temperature by blowing hot air through the line at 50 pounds per square inch (psi), the two-part epoxy coating was measured and mixed. The mixed coating was poured into polyvinyl chloride (PVC) pipe “dummies” prepared with quick disconnects on each end. The bottom of the dummy was sealed using thin polyethylene sheet material and the dummy connected between the sprinkler head pipe and the incoming air hose. Once the dummies were connected, the hot air at 50 psi was shot through the line. The high pressure air broke the polyethylene seal and forced the epoxy through the pipe toward the exhaust in a plug, lining the pipe. A second coat was applied after allowing the first coat to cure approximately 8 hours.

Once in place, the epoxy coating was protected from excessive heat (above 180 °F [81 °C]) and moisture (25 percent RH) while curing by blowing heated air through the pipe until the epoxy had an initial cure. Epoxy-coated pipe may be placed into service after continuous drying for 8-12 hours at approximately 70–75 °F (21–24 °C) minimum. Longer cure times may be required in areas where piping is subject to more severe (e.g., seasonal) and less-controllable environments (e.g., underground pipe, outdoor installations, etc). Cure times, temperatures, and environmental conditions are to be documented in the Epoxy Lining Progress Report.

After drying and curing, the epoxy coating consists of a minimum of one coat (5–7 mils thickness) over the entire substrate and shall not contain any of the following:

- Blisters
- Cracks
- Chips or loosely particles
- Oil or other contaminants
- Fisheyes, pinholes, voids, or other holidays.

Installing New Sprinkler Heads

All removed valves and fittings were re-installed once the epoxy coating was dry. New sprinkler heads were installed on all of the sprinkler outlets. Original valves and fittings determined to be overly worn or near inoperable were replaced following review by the Fort McPherson DPW and the Contracting Officer's Technical Representative (COTR).

Activating Fire Suppression System

The segment was activated following the leak test.

Testing the Activated Fire Suppression System

Following pipe cleaning and lining, the section/segment was pressure tested to confirm the absence of leaks. The lined piping system was tested with compressed air at 40 psi for 24 hours and verified to maintain pressure at +/- 10 percent of the test pressure.

Recertifying the Treated Pre-action Fire Suppression System

The completed fire suppression system was recertified. Upon completion of all segments, the lined system was tested as a whole utilizing the compressed air method of holding 40 psi for 24 hours as per NFPA 13. A 10 percent (+/-) differential is acceptable for this test. All testing was documented on the Epoxy Lining Production Report and made available for DPW review. After all testing of the lined system was complete, a Material and Test Certificate from a licensed fire protection contractor was provided to the Fort McPherson DPW and COTR.

5 Cost Analysis

Fort McPherson investigated the cost to replace the pre-action fire suppression system and discovered that it would require \$3,000,000.00 to perform the work. The contract to perform the in-place pipe lining work was \$289,162.00. Using the Office of Management and Budget methodology for calculating return on investment (ROI), the net present value of costs and benefit/savings is \$2,803,800 and the ROI ratio is 9.70.

6 Conclusions and Recommendations

Conclusions

The pre-action fire suppression system in the U.S. Army Reserve Component Headquarters, Building 315, at Fort McPherson was successfully lined in place with an epoxy liner. The lining process removed existing internal pipe corrosion, plugged up existing pinhole leaks, and provided a barrier to further pitting and corrosion from inside the distribution pipes. All of the sprinkler heads in the pre-action system were replaced with new heads. The system was pressure tested and recertified in accordance with NFPA requirements.

Recommendations

This process works well in addressing pitting and pinhole leaks caused by corrosion of fire suppression system distribution piping. Existing Army criteria should be modified to enable the in-place pipelining process for fire suppression systems. Guide specifications and engineering instructions should be developed.

References

Flinn, R. A., and P. K. Trojan. 1990. Engineering Materials and Their Applications, 4th Edition. Boston, MA:Houghton Mifflin Co., p S-6.

National Fire Protection Association. 2007. NFPA 13. Standard for Installation of Sprinkler Systems.

Society for Protective Coatings [SSPC]. 2000. SSPC-SP 10/NACE No. 2, Near-White Blast Cleaning.

U.S. Army Corps of Engineers. 1999. Engineer Manual 1110-1-4008, 5 May 1999, pp 4-1 through 4-6.

